HEALTHY RESPIRATION.

BY

DR. STEPHEN H. WARD.

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PREFACE.

THE Public cannot be expected to interest themselves in carrying out either general or special sanitary indications, so long as they remain ignorant of the principles upon which such indications are based. Intelligent conviction must precede energetic action. Such is the plea which the Author advances for the publication of the following Lectures, which were delivered last winter before a considerable London audience. Most of the facts and views contained in them may be met with in the leading works upon Hygiène; but these are either beyond the reach of the many, or, of so extensive a character, that much time and application would be necessary in order to master their contents. For the treatment of the subject the Author is responsible; and he trusts that he has expressed himself with sufficient emphasis, to induce others to throw themselves more trustingly into that broad physical relationship with external nature which it was the purpose of the Creator to establish.

28 Finsbury Circus.
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HEALTHY RESPIRATION.

LECTURE I.

RESPIRATION, or the act of breathing, considered in its relation to health, involves not merely an inquiry into the function itself, into the composition of the air we breathe and the mechanism by which we breathe, the changes induced in the blood and in the atmosphere, and the power by which respiration is effected and maintained, but has also a far wider scope, and embraces the various actions and conditions of life which may influence and be themselves influenced by the healthy or unhealthy performance of the function. The philosophy of dress, cleanliness, exercise, and, to a certain degree, of food, the various causes by which the purity of the atmosphere either within or without our dwellings may be impaired, the principle of ventilation, several of the more important questions bearing upon public hygiène, the influence

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upon epidemics of atmospheric conditions which are within our control, the importance of change of air, and, lastly, the means by which Providence maintains the purity of the atmosphere for the life of animals and man, fall legitimately within the comprehensive scope of the subject. Respiration, therefore, largely viewed, embraces problems immediately affecting our health and comfort; and its consideration derives additional importance from the fact that one-fifth, at least, of the mortality of this country is to be traced to diseases of the respiratory organs.

In the present lecture, I shall endeavour to explain clearly and fully the means by which respiration is performed, and its purposes, and subsequently shall consider the causes which promote or interfere with its effective mechanism and chemistry.

Breathing consists in a constantly sustained succession of movements, by which air is alternately taken in, and driven out through the mouth, throat and air-tubes from the lungs, in the cells of which it is brought into contact with the blood. It has for its object the removal, in the form of gas or vapour, of noxious materials from the body, and the purification of the blood; animating this fluid and the new food contained in it with the breath of life, and fitting it for the

nourishment of the body and the effective performance of various functions. For the attainment of this object, it is necessary that the blood should be brought into immediate contact with the atmosphere. This is effected in different classes of animals by an extension of surface in the form of a delicate membrane, beneath which the blood flows in countless hair-like vessels, and through which the necessary changes transpire. Such, throughout the animal kingdom, is the principle of the respiratory apparatus, whether it be exhibited in the form of hair-like appendages, tufts, feathers, gills, and so on, as in aquatic animals, or of tubes, sacs, and cavities, as in different terrestrial animals.

I might pleasingly engage your attention by taking in review the modification of simple means, which under Creative power has resulted in an infinite variety of forms adapted to a special purpose, and at the same time throw light upon my subject by showing the close connexion which subsists between the habits and activity of animals, and the energy with which their respiratory function is discharged. Referring you, however, to the comparative anatomist for instruction in these matters, I pass on to the consideration of the function as it exhibits itself in man.

The lungs, in man, are light, spongy structures

situated in the cavity called the chest, and having the heart between them in front. They vary, in size, according to the age and sex of the individual; being less developed in women and children than in men. They are made up of air-tubes and cells, blood-vessels, absorbent vessels, and nerves, compactly associated by a connecting tissue, and enveloped in a peculiar membranous sac or bag. The trachea or windpipe, through which air is introduced from without, branches off into two main tubes, one for either lung, which tubes again divide and subdivide, until, having attained extreme minuteness, they terminate in cells. To express the matter more familiarly, the twigs of the respiratory tree open each into cells, or an aggregation of cells, into which they convey the air from without; while beneath the membrane composing these cells, the blood circulates in a fine network of hair-like vessels. These vessels lie between the folds of the delicate membrane composing the walls of the cells, so that the blood coursing along them is freely exposed on both sides to the air. The air-tubes at their termination are frequently not more than the hundredth of an inch in diameter; from eighteen to forty cells being grouped around each. The cells vary from the $\frac{1}{120}$th to the $\frac{1}{1200}$th of an inch in diameter; the hair-like blood-vessels

spread out upon their walls being about $\frac{1}{3000}$th of an inch in diameter, and the spaces between the vessels being less than this. I may further remark, that, on rough calculation, there are at least six hundred million cells in the human lungs. Such is the marvellous contrivance by which an immense extent of surface is rendered compatible with remarkable compactness and economy of space! The arrangement and exquisite beauty of the structure so struck the discoverer, Malpighi, that he called it the *wonderful network*.

The cavity in which the lungs are contained somewhat resembles a beehive in shape, being contracted above and expanded below, and is familiarly known as the chest. Its walls are made up of different materials; of unyielding bony structure—ribs which form a large portion of the circumference of the cavity, the breast-bone which lies in front, and the spine behind; of elastic, yielding structure—the cartilages which are let in between the ribs and the breast-bone; and of muscles—a series of which fill up the spaces between the ribs, while one large muscle, the diaphragm or midriff, constitutes the floor of the chest, and separates its contents from those of the cavity below. Inspiration and expiration, or the actions by which air is drawn into or expelled from the lungs, are performed by the

alternate expansion and contraction of the chest produced by the action of the diaphragm, and the muscles situated between the ribs. In inspiration, the muscular floor of the chest, which, when in a state of repose, is convex above, descends; the muscles placed between the ribs draw these upwards and outwards, and by these two muscular actions the diameter of the chest is increased, both from side to side, and from above downwards. In expiration the diaphragm again rises, the ribs fall, contraction of the cavity is effected, and air is expelled. Dr. Arnott, who always very happily illustrates facts in physical science, observes, that when the chest is dilated, air rushes in through the mouth and windpipe, exactly as air rushes into a common bellows through its pipe, when the valve is shut, and the two boards are drawn apart; and air is again expelled from the lungs by the contraction of the chest, as from the bellows by the approximation of the boards. In order, he further observes, "that the air admitted to the chest should have the fullest action on the blood passing there, it was necessary that the spongy mass of lungs, in which the blood-vessels ramify, should occupy the whole of the cavity, and be equally distributed. Now, while the equable distribution is effected by the uniform elasticity or resilience which belongs

to the structure of the lung, the complete filling of the cavity is obtained, not by general attachments between the lungs and the ribs or sides of the chest, as might be expected, but by the following means equally simple and still more perfect. The spongy mass of the lungs is completely covered by a strong adherent membrane, called the pleura, through which air cannot pass; between this membrane and a similar lining of the chest there is no air or empty space, and therefore, in the rising and falling of the ribs during respiration, this membrane remains always in contact with the lining of the ribs, just as a bladder put into a bellows as a lining, with its mouth secured around the nozzle, is filled and emptied, and remains in contact with the interior of the bellows, in all the states of dilatation, as if there were attachments in a thousand places. This construction allows the lungs to have a singular freedom of play during all the motions of the body; a freedom farther provided for by their being divided into lobes, which slide one upon another."

Inspiration, as I have remarked, is effected by the dilatation of the chest, which is brought about by the active contraction of certain muscles. Expiration, on the other hand, is rather a passive process, and depends upon the contraction of the

chest which results when the muscles in question relax, and upon the natural collapse of the air-cells and smaller air-tubes of the lungs, in consequence of the elastic nature of the tissue of which they are composed; the expulsion of the air being further promoted by the contraction of muscular fibres which enter into the formation of the larger air-tubes. This latter action occupies only about half the time of the former.

Ordinary breathing is performed in a quiet and scarcely perceptible manner, the only muscles engaged in it being those already noticed. When, however, any considerable increase of the function is demanded, respiration becomes, as physiologists term it, extraordinary, and other auxiliary sources of muscular action, muscles situated about the shoulders and back, are brought into play. This occurs under violent exertion, and in certain diseases; the energy of the action being, under some circumstances, so intense, that a large number of muscles situated about the face, neck, chest, and back are engaged in the one main purpose of dilating to the greatest extent the chest, so as to ensure a sufficient supply of fresh air.

In order to comprehend perfectly the respiratory process, it is necessary to glance at the apparatus by which the blood is distributed over the body and to the lungs. This consists of the

heart and blood-vessels; the vessels which carry the blood from the heart being termed arteries, those which bring it back to this organ being called veins. The position of the heart has been already indicated. It consists of four cavities, two on either side. From the lower one on the left side, the blood is distributed through a large artery and its countless branches all over the body, nourishing it and building up various tissues, and performing the main part in the functions of the different organs. Having thus lost much of its life-sustaining material, it is carried by the veins back to the upper cavity on the right side of the heart, altered in its character, containing noxious matters which require to be separated from it, and other ingredients which require exposure to the vivifying influence of fresh air. It passes therefore from the upper to the lower cavity, which forces it along arteries to the lungs, where, in the network of vessels in the cells, it becomes renewed, is taken up by other vessels, and brought to the upper chamber on the left side of the heart. From this it passes to the chamber below, by the contractions of which it is again thrown over the system. There are thus two circulations, one for the body, the other for the lungs; one for the sustenance of life, the other for the renovation of the life-sustaining fluid.

The contraction of the heart produces the impulse or beating of that organ, and also the pulsation of the arteries, the pulse, which is so distinctly felt at the wrist, and in other situations where the vessels lie close to the surface. With each beat of the heart there is sent through the lungs about 2 ounces of blood. The number of beats per minute is, in an adult, from 70 to 75; and the entire quantity of blood in the body is estimated at one-fifth of its entire weight,—24 to 28 lbs., or 20 to 22 imperial pints. On this calculation there will be one circuit of blood performed in somewhat less than 3 minutes, and about 540 in 24 hours. Let us see what relation the function of respiration bears to this. There is in ordinary tranquil breathing about 1 respiration to 4 beats of the heart, 18 therefore in a minute, and 25,920 in the 24 hours. With each respiration of a perfectly easy kind, about a pint of air is taken into the lungs, and a similar quantity of vitiated air is expelled; several pints, from 8 to 12, remaining in the lungs after each expiration. Various causes, such as the degree of development of the chest, the healthy condition of the lungs, the effective character of the expiration, will of course modify the quantity of air which each individual may be able to inspire. The greatest quantity of air that an ample pair of

lungs has been found capable of receiving at one inspiration is between 9 and 10 pints. Many public singers are able, from practice and constant direct exercise of the organs in question, to inspire 6 or 7 pints, and thus produce the sustained notes which give rise to thrilling effects. In order that you may have a more general estimate of the quantity of air in relation to that of blood, I may remark that, according to the calculation of Mr. Finlaison, 57 hogsheads of air are inhaled in 24 hours to oxygenate 24 hogsheads of blood.

Such, then, is the mechanism of respiration. In order to ensure the effective purification of the blood, the heart beats from 60 to 80 times in a minute, and in the same space of time the chest alternately expands and contracts from 15 to 20 times; and these actions continue without intermission through the longest as well as the shortest life, whether we are sleeping or waking, in disease as well as health. Our "bosom's lord sits lightly on his throne;" other actions induce weariness; these know it not!

Before I proceed further with my subject, I must bestow a passing glance upon one or two applications of physical laws to the detection of disease. The air, in passing into and out of the lungs, and more particularly in entering, in overcoming friction and displacing other air, produces

a sound which is very audible to the ear placed against the outside of the chest; the sound produced as the air passes along the larger air-tubes being different from that which it produces when penetrating into the small tubes and air-cells. The voice also of an individual, when speaking aloud, causes a vibration of the walls of the chest, which may be felt by the hand applied externally, and its resonance may be clearly heard in certain situations. Now, the situation and intensity of these sounds in health, other circumstances being alike, are pretty accurately defined; so that any marked deviation from the healthful character becomes an indication of disease. It is unnecessary, and would perhaps be injudicious, for me to dwell upon this matter. I will therefore only remark that the stethoscope, which exhibits itself to the ignorant in a somewhat mysterious light, is nothing more than a good conducting medium of sound between the chest and the ear; the application of the latter immediately upon the chest being, in some cases, obviously objectionable. This instrument was invented nearly forty years back by a French physician named Laennec. Having to examine a young woman affected with heart disease, and not liking to apply his ear to the chest, he bethought himself that solid bodies conduct sound better than air. He accordingly

took a quire of paper that was at hand, rolled it up very tightly, tied it, applied one end to the patient's chest, the other to his ear, and found that he could hear the beating of the heart much more distinctly than he could feel it. This, the first stethoscope, was soon replaced by one constructed of wood, and from that time, in the examination of chest affections, the sense of hearing has been to medical men what sight and touch are in other cases.

Another indication of the healthy or unhealthy condition of the lungs has been based upon the quantity of air which an individual is capable of exhaling after a full inspiration; and an instrument called a *spirometer*, a measurer of breathing, has been devised by Mr. Hutchinson for this purpose.

The chemical part of respiration, which we must now consider, embraces the changes produced in the air and in the blood, and cannot be understood without a previous glance at the composition of the atmosphere.

Atmospheric air, simple as it appears, consists, as many of you have already learnt, of different gaseous elements; differing in qualities, but happily blended in the proportions adapted to the necessities of life. Of these elements, oxygen and nitrogen are the principal; both, like air itself,

being devoid of colour and odour, but otherwise differing materially in character—oxygen supporting the combustion of any burning body most vividly, and acting as a high vital stimulant; animals when immersed in the undiluted gas exhibiting great excitement, and living as it were far too rapidly; nitrogen, on the contrary, exhibiting negative properties,—not being, on the one hand, a positive poison, but, on the other, not supporting combustion or life, and acting in the atmosphere as a diluent of the oxygen, diluting it, and diminishing its strength, as water does that of wine or spirits. A third gas, carbonic acid—not elementary, but composed of oxygen and carbon—constitutes a very small portion of the atmosphere: it is heavy, destructive to animal life, but essential to the existence of plants. Besides the above gases, there is diffused through the atmosphere, in a proportion varying from the 60th to the 200th of its bulk, a quantity of watery vapour.

Now, atmospheric air has been most carefully analysed by philosophers in different quarters of the world, and at various heights, from the sea-level to Mont Blanc, and the great peak of the Andes, Chimborazo, where it was examined by Humboldt and his companions. It was also analysed by Gay-Lussac, at the height of 23,000

feet above the sea-level, to which he ascended in a balloon. In whatever quarter or altitude it has been tested, it has been found invariably to be made up of the constituents just noticed, in the same proportions; viz., in 100 volumes, of about 21 parts of oxygen, 79 of nitrogen, the $\frac{1}{20}$th part of a volume of carbonic acid, or 1 part in 2000, and a variable quantity of watery vapour. These different constituents are not chemically, but, as I have said, only mechanically combined.

There is, however, something more in this admixture, well meriting our attention. While the entire bulk of the atmosphere obeys the great law of gravitation, by which bodies are attracted towards the earth, and is dense in proportion to its proximity to the earth's surface, the gases of which it is composed, in common with other gases, obey also a different law, known as the *diffusion* law. In obedience to this they become intimately blended, frequently rising against their specific gravity, and overcoming what we should consider insurmountable obstacles. Impelled by this law, oxygen, or carbonic acid gas, if confined in a glass vessel which communicates by a narrow tube with another glass vessel above containing hydrogen, will be found in a very short time to have risen against its specific gravity into the upper vessel,

the hydrogen having descended against its specific gravity to the lower, and both to have become intimately blended. Impelled by this law, the different gaseous constituents of the atmosphere, instead of being found in three distinct strata—the heavy carbonic acid below, rendering life impossible, the lighter oxygen in the middle, and nitrogen, the lightest of the three, at the top,—are found in the highest altitudes to be intimately mixed, in exactly the same proportions. The specific gravity of the gases does, however, exert some influence; lighter gases becoming more rapidly diffused than those which are heavier. By-and-by I shall consider the importance of this diffusion law in maintaining the atmosphere free from accumulations of impurities with which it is daily charged from animal life, from combustion, and from various chemical changes in the inorganic world. At present we must proceed with our inquiry into the function of respiration and its objects.

The contact of atmospheric air with the blood takes place in the air-cells, in the walls of which the delicate hair-like blood-vessels ramify. The cells themselves are microscopic objects, and the tubes that lead to them are only from the 50th to 100th of an inch in diameter. Now, the comparatively coarse mechanism of bone and

muscle, and elastic tissue, which we have already considered, is available only for the introduction into the larger tubes and their divisions, of fresh air, which would never reach the structure in which the purpose of respiration is really effected, but for the diffusion law. By means of this, the carbonic acid in the cells rises through the air in the tubes, the latter descends, and thus the change is effected.

But there is yet another admirable instance of Providential purpose to be considered in connexion with this part of the function of respiration. The heavy carbonic acid gas, in compliance with the modification of the law just noticed, would not pass out from the blood-vessels with sufficient rapidity, and the blood would not become purified as readily as is requisite for the maintenance of life, were not some other provision made. Now, carbonic acid is very freely soluble in water; and, consequently, passes most readily through a wet membrane, such as that forming the air-cells and spread over the vessels; being rapidly taken up by the fluid with which such membrane is saturated, and again given out, while, by the same process, oxygen passes in. The change is also, in some degree, promoted by the different temperature and, consequently, different density of the air within and external to the lungs. There is also

another unseen influence at work. When describing the structure of the air-tubes, I forgot to mention that the membrane which lined them was covered with innumerable microscopic hair-like processes, called cilia, which, during life, are in a state of perpetual vibration. The continual vibrations of these cilia serve to prevent the adhesion of the air to the moist surface of the membrane, and thus aid in facilitating the process.

The air, then, that is taken into the lungs, consists of oxygen, nitrogen, and carbonic acid, in the proportions I have mentioned. On being expired, considerable changes are found to have taken place in it. The first change, which any one may perceive, is, that, in mild climates at least, it has acquired an increase of temperature. The second, of which every one is cognizant on a cold, damp morning, is, that it contains more watery vapour; the little cloud then formed on expiring being due to the condensation of watery vapour in an atmosphere already charged with it. On subjecting the exhaled air to chemical analysis, it is discovered that the relative proportion of component parts is considerably modified. The quantity of carbonic acid is found to have increased from the $\frac{1}{20}$th of a volume in 100 to four or five volumes; while that of oxygen has diminished from twenty-one to sixteen volumes, or even less.

The amount of oxygen is, in fact, less by a fourth or fifth of the previous quantity, while there is one hundred times more carbonic acid. It was supposed that the oxygen which had disappeared was exactly replaced by that contained in the additional quantity of carbonic acid which is given out; but such, as I shall show you presently, is not the case. The nitrogen is considered by Dumas and other chemists not to be absorbed by blood, but to be exhaled from the lungs in the same quantity as was inhaled.

The lungs give out a considerable quantity of watery vapour, a quantity varying from six to nearly thirty ounces in the twenty-four hours. It passes off by simple evaporation from the surface of the membrane composing the minute air-cells and tubes; such evaporation being favoured by the naturally high temperature of the human lungs. The quantity of aqueous vapour which is thus exhaled is, of course, influenced by the quantity of air inhaled, by the extent to which this is previously saturated with water, and also by its temperature; for the higher this is, the greater will be the quantity of watery fluid required to saturate the air.

This is perhaps the best place to notice the part played in the function of respiration by the skin. This is not a mere covering of the body,

but a complex organ, performing duties essential to existence. Immediately beneath the skin is an amazing number of little glandular bodies, each of which is furnished with a duct, or tube, which takes a spiral course to the surface; the apertures of these ducts being visible to the naked eye in certain parts of the body, as the sole of the hand or foot. According to Mr. Erasmus Wilson, there are 3528 of these in a square inch of surface on the palm of the hand, the average being 2500 for every square inch of surface, making a total of about seven millions throughout the body. Each tube, when straightened out, is about a quarter of an inch long; so that if all the perspiratory tubes, as they are called, in the body could be placed end to end in a line, they would extend to 1,750,000 inches, or little less than 28 miles. Such are some of the minute organs of the human frame, revealed to us in the full beauty of their structure by the microscope. Now, from these glands there is always passing off a considerable quantity of watery fluid, varying in the 24 hours from 20 ounces in colder, to 40 ounces in warmer climates and seasons; the quantity being also influenced by other circumstances, and especially by physical exercise. It has been experimentally proved, however, that the little organs in question not

only free the system of superfluous fluid, but that they also give out a quantity of carbonic acid gas, while they abstract from the air a portion of its oxygen. The amount of carbonic acid gas so exhaled is considerably below that which is exhaled by the lungs, but still is of appreciable importance.

Physiologists and chemists differ somewhat in their calculations of the quantity of carbonic acid set free from the lungs and skin in the course of every 24 hours. Sir H. Davy came to the conclusion that about 38,000 cubic inches of carbonic acid gas (between 21 and 22 cubic feet), containing 5000 grains of solid carbon or charcoal, were disengaged in this period of time—about $\frac{4}{5}$ths of the quantity being exhaled from the lungs. Liebig places the quantity of carbonic acid given out in this period at about 19 cubic feet, containing about 13 ounces of solid carbon : the average in ordinary and comparatively tranquil life is probably lower than this. Dr. Scharling went to work very carefully and systematically, in order to determine the exact quantity given out by different individuals. He constructed an air-tight wooden chest, capable of containing one person at a time. A constant current of pure air was thrown into this chest by one tube, while by another the vitiated air was drawn off and tested. The box

was furnished with a glass window, and was sufficiently roomy to enable the person confined in it to turn about, amuse himself in various ways, and, in short, be as comfortable as any one could be who was conscious that he was the subject of an experiment. The following are the results of Dr. Scharling's experiments, upon six individuals, as to the quantity of carbon given off:—

	Age.	Weight in Danish lbs.		grs. oz. Troy.
1. Man	35	131	in 24 hours	3386 = 7·05
2. Ditto	16	115½	" "	3462 = 7·21
3. Soldier ...	28	164	" "	3698 = 7·70
4. Girl	19	111⅓	" "	2559 = 5·33
5. Boy	9¾	44	" "	2054 = 4·28
6. Girl	10	46	" "	1935 = 4·03

The energy of the respiratory movements, and, consequently, the quantity of carbonic acid exhaled, vary under different conditions. A larger quantity of the gas in question is given out by men than by women; the amount being greatest between the ages of 30 and 40, less in childhood, and considerably diminished in extreme old age. It varies also in the same individual; being more considerable in winter, and under exposure to severe cold, than in warm seasons. Moderate exercise and the process of digestion seem to increase the exhalation of this gas; while during sleep, when the respirations are less energetic, it is palpably diminished.

Messrs. Andral and Gavarret experimented upon seventy-two different subjects, men and women, in order to determine the circumstances which modify the generation of carbonic acid, and arrived at results confirmatory of the general statement I have just made. They showed, that while the quantity exhaled is but little influenced by the weight or stature of any individual, it is materially so by age, sex, and other circumstances which concern more peculiarly the medical man. The experimenters just noticed placed the quantity of solid carbon given out from the body at nine ounces in every twenty-four hours.

Let us now consider the changes induced in the blood on its being brought into contact with the air in the cells. As most of you are doubtless aware, there are two kinds of blood in the body; one, bright florid-red in colour, circulating out from the heart along the vessels called arteries, to perform various functions in every part of the system; the other of dark claret colour, called venous, laden with impurities and effete matter, containing also food not yet quite converted into blood, and carried by vessels called veins back to the heart, and by it sent to the lungs for renovation. This dark blood, on becoming exposed to the air in the cells, immediately acquires the bright red arterial colour, and is found on analysing it to have

undergone certain changes,—to have parted with a certain portion of carbonic acid and water, and to have taken up more oxygen; the difference between the two kinds of blood being represented in the following table by Magnus:—

	Arterial blood.	Venous blood.
Carbonic acid...............	62·3	71·6
Oxygen	23·2	15·3
Nitrogen....................	14·1	13·1

More oxygen, however, is taken into the capillary vessels than is represented in this table; more, in fact, of this gas passes inwards to the blood, than of carbonic acid outwards to the tubes. This difference is accounted for by the modification of the diffusion law which I have already noticed. What becomes, then, of the excess? It appears probable that a portion of it combines with, and gives a higher vitality to the coagulable part of the blood, which is called fibrin, and which subsequently goes to build up tissues. Another portion would seem to exert some chemical action upon the red particles of the blood, and determine the change of colour. The rest combines with hydrogen to form the watery vapour.

Now, the combination of hydrogen with oxygen to form water, and of carbon with oxygen to form carbonic acid, is invariably accompanied with the evolution, the giving-out, of heat. This is, in fact, that which takes place in the ordinary com-

bustion of a candle, lamp, or the materials burnt in a stove. The heat which the human body generates and possesses quite independently of external temperature, is due to such combinations ever going on within it: chemists have, therefore, not unaptly likened it to a furnace; and our great dramatist happily expresses a physiological truth when he speaks of life as "a brief candle."

Food supplies materials, part of which goes to build up the tissues and support the frame, while another part is burnt, either directly or after a time, in the process of respiration. This combustion, though gradual and unattended with the phænomenon of flame, is not the less effective. The lungs, however, as Liebig observes, are not the fire-place in which this combustion goes on. In the first place, they have no higher temperature than other parts of the body, as they certainly would, were this kind of slow fire always burning in them. Secondly, animals confined in nitrogen gas continue for a time to give out carbonic acid, which shows that this must have previously been formed in the system. And, thirdly, the excess of carbonic acid is actually detected in the impure or venous blood which flows back from different parts of the body towards the heart. It appears pretty evident, therefore, that the union of carbon and hydrogen with

oxygen, and the heat given out in consequence, instead of being confined to the lungs, is effected in the capillary vessels all over the system.

There is something very admirable in this association of the function of respiration with the production of independent animal heat. Without respiration, life could not be prolonged even for a few minutes; without the power of generating animal heat, and maintaining it at the same standard under extremes of heat and cold, man's health, and, ultimately, his existence, would be impossible. Without such provision, the blood, in the colder seasons of our temperate climes, and in the arctic regions, would become congealed in its vessels, and fluid vital functions would cease to be performed. The Esquimaux, North Americans, and other inhabitants of very cold countries, resort to the peculiar kind of diet—fat, oil, &c.—which contains much hydrogen and carbon, and therefore best co-operates with the respiratory function in maintaining the animal heat. The food sought out by the inhabitants of such regions contains considerable quantities of fat, the carbon and hydrogen of which are employed in the production of animal heat. "These people live by hunting: the muscular exertion required quickens and deepens the breathing; while from the increased density of the air, a greater weight of

oxygen is taken into the lungs, and absorbed into the blood at each inspiration. In this manner the temperature of the body is kept up, notwithstanding the piercing external cold; a most marvellous adjustment of the nature of the food, and even of the inclinations and appetite of the man, to the circumstances of his existence, enabling him to bear with impunity an atmospheric temperature which would otherwise injure him*."

Respiration, then, consists in the giving-out of carbonic acid and the taking-in of oxygen; the blood being thus purified and rendered more stimulating and better fitted for the purposes of life. It is clear that for the effective discharge of this important function a constant renewal of the air to be breathed is essential. If this be not ensured, it becomes gradually more charged with carbonic acid, until, in a short time, it is inadequate to the support of life. Carbonic acid, in excess, acts as a positive poison, by preventing the absorption of oxygen; the blood, at the same time, being unable to free itself of its carbonic acid. The same air, on being breathed over and over again, becomes more and more charged with this poisonous gas. The blood brought into contact with it does not undergo its usual and necessary change, but is again circulated over the

* Fownes.

body in more or less the same condition in which it came to the lungs for aëration. The first effect of this impure blood upon the system is to induce uneasiness and torpor; death ultimately resulting if the air be not renewed. When the blood undergoes no purification at all, but remains dark and venous as when brought to the lungs, its re-circulation induces rapid insensibility and death, which may be preceded or not by convulsions.

I have thus considered, somewhat closely and critically perhaps, the mechanism and chemistry of respiration, and, in doing so, have, I know, incurred the risk of tasking your patience. But, in dealing with nature, no fact must be omitted, every phænomenon must be dwelt upon, or we lose some connecting link in our history, we drop some portion of evidence necessary to complete our, at best, imperfect idea of the perfection exhibited in Creative design. And before we can be said fairly to have grasped this part of our subject, we have to contemplate the nervous or vital power by which the mechanical actions and chemical processes which we have considered are brought about.

Now, I may state at once, that this most important function of respiration is carried on independently of our will. If we could arrest for an indefinite period the action of the muscles

concerned in this function, in the same way as we can move an arm or leg, or any other part of the body at our pleasure, life would not for a moment be secure. We can, it is true, put a stop to respiration, hold our breath for a few moments, but the demand for fresh air becomes then so imperative, the sensation so urgent and distressing, that we are forced to yield to it. The will, too, is capable of usefully controlling the acts of inspiration and expiration so as to make them subserve the production of the voice, and its modulation in whispering or speaking aloud, in shouting, singing, and so on. Certain mental emotions also, as fear, grief, rage, or joy, may retard or quicken the respiratory movements, or modify them, as in laughing, sobbing, and sighing. In the main, however, the movements in question are quite independent of the will and of the influence of the mind. How then are they brought about? I shall, perhaps, enable you to understand the matter by glancing at different conditions under which movement of certain portions of the body, of the legs for instance, may be effected. An individual may desire to move from one point to another; the will to do so is transmitted along certain nerves to the proper muscles, and the movement takes place. The same individual, however, may perchance fall from a height, and so injure his spine as to cause

paralysis of the lower part of the body. While he lies prostrate in this condition, no exercise of the will can induce the slightest movement of either leg, and the severest irritation of them, even an extensive burn, is unfelt. If now the foot be tickled with a feather, though the individual feels it not, it excites at once movement of the muscles. To actions such as this last the term reflex—reflected—has been applied, and it is to this class that the respiratory movements belong. Reflex movements emanate from that portion of the nervous system called the spinal cord. Impressions of which we are not conscious, made upon the extremities of nerves at the surface of or within the body, are conveyed along the nerves to the spinal cord, just as the impressions made upon the notes of a piano are conveyed along the strings to the sounding-board; from the cord the impression is reflected along other nerves to muscles, which are set in action in consequence.

The chief source of excitement of the respiratory movements is in the lungs; the venous blood flowing into the capillary vessels, and the carbonic acid passing out into the air-cells produce an impression upon the branches of certain nerves, which is conveyed by these to the upper part of the spinal cord, and then carried by other nerves to the midriff, which is set in action. The im-

pression made by one inspiration may probably assist in exciting the next. Almost the entire surface of the body is, however, identified with this vital function: nerves in the face, over the body, and even on the limbs, may convey impressions to some of the muscles that are engaged, at times, in producing the movements of breathing. That such is the case is well shown by the sobbing, the spasmodic respiration, which instantly follows a plunge into cold water of any considerable part of the body.

That portion of the nervous system which presides over the respiratory functions is situated at the upper part of the spinal cord just within the base of the skull, where it is most effectually protected against external injury. It is, indeed, only from pressure upon or division of the spinal cord above the origin of the nerves which transmit the moving power to the diaphragm that death instantly ensues. The entire brain may be removed, and the lower portion of the spinal cord destroyed, but the functions of the part in question continue. It is indispensable to existence that this portion should be in a state of constant energy and activity; and hence we find that it is not influenced, either in health, when other actions are temporarily suspended, or during some of the severest disorders of other parts of the nervous system.

In deep sleep, when the mind is shut out from the external world, when the limbs lie relaxed and motionless, and the animal life of the man is for the time extinct, the heart still beats, and the muscles of respiration still act, more slowly it is true, but yet with measured regularity.

A man, the father of a family perhaps, is stricken down with apoplexy. The brain, the organ through which his mind acts, is paralysed; he hears not, sees not, feels not, perceives not; the world for him is a blank; but the breathing still goes on. If the attack terminate fatally, this function is the last to be involved; and, if it pass over, and the man is again restored to his wife and children, it is because this function has throughout remained intact.

A fair, delicate young woman suddenly receives news of the death of husband or lover, and falls down, as though smitten by death, in a swoon. It would be kindness, but is not duty, to let her die. Water is sprinkled over her face, or she is brought to the open window, and the evening breeze is allowed to play upon her. She feels it not, but presently a deep sigh or sob shows that the muscles of respiration are acting responsive to the impression. The lungs and heart are thus excited to renewed action, and the brain receives once more the stimulus

necessary for the restoration to consciousness and life.

Man is either ignorant of, or reflects not upon these things; but I know of nothing in the host of marvellous Providential designs more marvellous than this—that actions thus immediately essential to life should be executed by means entirely independent of our consciousness and will.

LECTURE II.

In the present lecture, I shall consider the circumstances associated with our every-day life which tend to interfere with the effective, healthy performance of respiration, and shall review in the first place, the different causes that influence, prejudicially or otherwise, the mechanical part of the function. Stocks and stays at once suggest themselves to the mind. The former, however, when too deep and unyielding, such as those with which our soldiers were throttled until very recently, act rather by preventing the return of blood from the head and inducing a tendency to apoplexy, than by interfering with the entrance of air into the lungs.

Catherine de Médicis has the credit of having introduced into France the fashion of compressing the chest by a curious apparatus or framework of whalebone, ostensibly, no doubt, on the ground of preserving symmetry and giving support to the body. Steel was shortly after substituted for whalebone. The fashion of course soon found its way into England. The original purpose of the

article of costume became lost sight of; the fair sex vied with each other in efforts to realize the tapering waist, and the central constriction of the wasp came to be regarded as the model of grace and elegance. But quiet observers of life and manners, in frequenting the ball-room or assembly, remarked that towards the close of the evening, the countenance of many a fair dame would be unnaturally flushed, and the breathing short and hurried. After a time, too, the bills of mortality, such as they then were, indicated a large increase of consumption among the female part of the community. Forthwith the philosophers came out of their hiding-places, and preached a crusade against the corset. They excited interest in high places, and a king thought it right to issue an edict severely forbidding the use of the costume in question. But the liberty of the subject was not thus to be interfered with, and the practice maintained its ground. There is, I believe, now, every reason to feel convinced that, through the good sense and improved education of our countrywomen, the practice, in its abuse at least, is rapidly going out of fashion. Let us, however, for one moment, glance at its mingled mischief and absurdity, for, from observation, I know that it is still necessary to speak seriously of it.

I might have introduced, by way of illustration,

a representation of a chest distorted by tight lacing, in which the ribs are forcibly compressed, and the lower part of the cavity, instead of being the more expanded, is the more contracted part. The effect of such compression is to prevent the actions of the muscles between the ribs, by which these are raised, and drawn outwards, and the chest dilated in inspiration; the movements of respiration being thus limited to the diaphragm. The consequence is, that respiration is hurriedly performed, while indigestion also results from pressure on the organs connected with the digestive function. The pressure is made, in fact, directly over the heart, lungs and liver; the free action of these is, therefore, seriously interfered with; and they have even been found, after death, displaced from the situation which they ought to occupy. Dr. Combe says: "Estimating an ordinary inspiration in a healthy young woman to be 20 cubic inches of air, and supposing that, from excessive compression, the expansion of the lungs be reduced so far that only 15 inches can be inhaled at each inspiration, it will not be difficult to understand the deleterious influence produced by it on the general health and on the lungs themselves." There will, in fact, be one-fourth less oxygen inhaled at each inspiration. Some years back, the Registrar-General attributed an excess of 4000

deaths from consumption in women over men, during one year, to the habit we are considering.

It would be interesting to inquire into the philosophy of the attempts which man everywhere makes to improve upon nature, and occasionally one seems to hit upon a solution in the exaggeration of that which is the prominent feature of a race. It is not, however, for us, to ridicule the foolish fashions of other races; these are, for the most part, innocent, compared with that wasp-like contraction of the chest, by which the action of vital organs is too often seriously impaired. I might ask you to compare such a contracted waist with some of the Greek ideals of beauty; but there is no necessity to fall back upon the creations of the sculptor to ascertain the ample symmetry of nature. Travellers tell us that it may be found even in savage life—not only in the Circassian and Georgian, but in the Polynesian, the American Indian, and even in the Negro. The line of health is, in fact, ever the line of beauty.

Certain pursuits, especially those of a sedentary character, prevent the free action of the muscles and expansion of the chest. When an individual—a student, literary man, or artisan—is sitting for several hours together at a table, engaged in writing, reading or manipulation, the body, and especially the chest, is constrained, the

respirations are not as free and full as they should be, and the blood is not effectively aërated. I have known the function of digestion as well as respiration seriously impaired by a habit of leaning the chest against a desk, which is not unfrequent with clerks and others. Those, consequently, who are compelled to devote a considerable part of every day to reading and writing, should, from time to time, vary their position, and, by means of a raised desk, pursue their occupation in the erect attitude. Considerable compression takes place in certain trades where the body is bent. Shoemakers, tailors, &c. sit almost doubled up, so that it is scarcely possible for them to take a full breath. But perhaps the greatest combination of prejudicial influences is to be met with in the case of milliners, especially the inferior hands. Under the flattering idea of being apprenticed to a trade, young women are frequently taken from home almost in childhood, or at any rate before their development is complete. They are placed in a room closely packed with human beings, where they remain, day after day, sitting in constrained attitude over their needlework, in an atmosphere rendered impure during the day by the products of respiration, and still further vitiated at night by the combustion of gas. But a scant interval is allowed for meals, none for exercise, and the habit,

perhaps, of tight lacing still further diminishes the supply of air that should reach their lungs. Such is, too often, the daily life of these unfortunate young women; and then to all this are added, during the *furore* of the fashionable season, on the eve of every great ball or fête, serious inroads upon the hours that should be given to the restoration of the strained sight, the aching brain, and wearied limbs. Can the rifeness of consumption and severe nervous affections among this class be a matter of surprise?

Other occupations interfere with the effective performance of respiration by causing direct mechanical irritation of the air-passages, and by clogging up the cells; thus interfering with the mechanism as well as the chemical part of the function. The evolution of fine dust incidental to particular trades is apt to cause this state of things; hence it is that bakers, millers, starch-factors, flax-workers, steel-filers and polishers, stone-masons, &c. constantly fall victims to severe chronic bronchitis, or consumption. When wandering through the picturesque country about Fontainebleau, I was struck with the powerful and healthy aspect of the men engaged in working at the sandstone quarries. On inquiring about them, however, I found that but few attained the age of fifty, the greater proportion dying before

that age, of consumption engendered by constantly inhaling an atmosphere charged with fine particles of stone. Workers in coal mines suffer in a similar way, and also from a complication of other causes, as deficiency or deprivation of solar light, excessive work, and the constrained position in which they are compelled to work, humidity, and, in addition, generally, bad food, insufficient sleep and clothing. The effect of all this is to arrest development in the young miners, to give rise to rickety limbs and curved spine, and induce difference of height and configuration in them as compared with others of the same age who are employed in agriculture. The chief effect, however, is produced upon the respiratory apparatus, from the inhalation of fine coal dust and of noxious gases. This gives rise to difficulty of breathing, and after a time, perhaps between the ages of twenty and thirty, to a chronic bronchial affection attended with the expectoration of black fluid, which is called the "black spit," and which generally terminates fatally before the age of forty.

The smoke diffused through the air of large towns acts partly as a mechanical irritant, and partly by conveying to the air-tubes poisonous gases which are entangled in it. A removal of this nuisance would not only be beneficial to health, but also of considerable moment in an econo-

mical point of view, by diminishing the necessity for washing and painting, and rendering the air more fitted for vegetable life. A curious proof of the prejudicial action of smoke upon plants was afforded in London during the ravages of the Great Plague. In consequence of the diminution of the inhabitants by death and absence, a far less quantity of smoke was evolved than usual; and, from the purer condition of the atmosphere, many trees acquired higher vitality, and blossomed.

Moderate direct exercise of the lungs, as in speaking, reading aloud, singing, and playing on wind instruments, tends to develop and strengthen the chest and organs engaged in respiration; while general exercise of the body, in the form of various athletic sports, walking, riding, and so on, indirectly contributes to the same effect. Exercise acts in the following way. The muscles, in contracting, press upon the blood-vessels, propel more rapidly the blood contained in them, and thus increase the force and quickness of the circulation. The vessels upon which the muscles thus press are the veins which are carrying the blood back to the heart. This organ, receiving the blood more rapidly than usual, takes on increased action, and transmits the blood more quickly to the lungs, which become temporarily overloaded.

Hence the quick, hurried breathing, which is one of the first consequences of violent exercise. If the exertion be continued, the impulse is propagated through the whole course of the circulation, and the balance between it and the respiration is to a certain extent restored, though the breathing remains fuller and freer than before. Exercise, also, by promoting the free action of the skin, assists the lungs in freeing the body from useless and noxious materials. In childhood, when the body is yet plastic and may be moulded either to physical weakness or strength, a due amount of unrestrained exercise is of the utmost importance; tending to the development of the chest and limbs, and to the promotion of muscularity and vigour. There can be no more fatal error than that committed by many parents, who, over-anxious for the mental improvement of their children, keep them daily confined for hours together in a constrained position over their tasks.

From the important aid which is afforded to the function of respiration by the skin, it follows that every means should be had recourse to, to maintain the health of this complex organ, as I would call it. The means by which this must be effected consist in frequent ablution of the entire surface of the body. During the warmer period of the year, the daily use of the sponge, shower,

or plunge bath, is indispensable; indeed, such a practice is desirable at. all seasons. When constant ablution is not had recourse to, the delicate ducts of the perspiratory glands, which I noticed in my last lecture, become blocked up by the solid matters deposited from their own secretion, and, also, by extraneous particles. The obstruction which is thus caused to perspiration tends to induce disease of the skin itself, to disturb the balance, as it were, of the system, and, by throwing more work on the internal organs, especially upon the lungs, to increase their liability to disease. Coughs, colds, and consumption are far more frequent in individuals who are indifferent to cleanliness than in others with whom it is a daily habit.

I must now take in review the causes which interfere with the chemistry of respiration. I shall first consider those which vitiate the air within, and afterwards those which affect that without, our dwellings.

The function of respiration itself is one of the most immediate and constant sources of impurity of the air which we breathe in our homes. It has been proved that seven or eight parts of carbonic acid in one hundred of atmospheric air are requisite in order to destroy life, but that a very much smaller proportion than this, one to two

parts in a hundred, will cause much distress. A calculation has been made, to the effect, that the population of a crowded district, in respiring for twenty-four hours, vitiate a layer of air a yard in depth, and equal in extent to the space inhabited; and one may easily understand from this the condition of the air in a close, crowded room, from the effects of respiration only. Dr. Combe, reasoning upon Mr. Finlaison's results, to which I have already alluded, observes, that if one individual inhales and deteriorates fifty-seven hogsheads of air in twenty-four hours, twenty-four individuals will deteriorate the same quantity in one hour; and one hundred people enclosed in a room for an hour in attendance upon a lecture, breathe in that time 228 hogsheads of air, consume forty-eight hogsheads of its oxygen, and vitiate it by a proportionate bulk of carbonic acid. Such a quantity of poisonous gas so thrown into a room not effectually ventilated could not fail of producing most unpleasant effects, as languor, headache, heaviness, nausea and fainting. Such effects are indeed frequently produced in badly-ventilated theatres, ball-rooms, churches, &c., and they illustrate in a most complete and practical manner the importance of providing for a constant renewal of the air. When people have been crowded together in a small space, and no

change of air has been ensured, death has soon resulted. Of the 146 persons who were thrust into the memorable Black Hole at Calcutta, only twenty-three came out alive at the end of ten hours; and nearly all these were in a state of putrid fever. Similar fearful results have frequently occurred in slave-ships from packing the victims too closely, but have failed to excite due attention and indignation from the circumstance that negroes were the subjects of the cruelty instead of white men.

Another source of impurity of the air within doors is from the emanation of sundry particles from the skin, which were actually detected by Dr. Smith in the air and on the walls of rooms, and were proved by him to undergo decomposition, and give rise to unpleasant and unwholesome odours.

A most prolific cause of atmospheric vitiation in rooms inhabited by human beings is the process of combustion from fires and artificial lights, which process, like respiration, charges the air with carbonic acid and watery vapour, and abstracts its oxygen. Different artificial modes of illuminating a room vary in the changes they produce in the atmosphere. Tallow candles give rise, not only to carbonic acid and water, but to particles of soot, and, from the volatilization of the fat, to

certain acids and empyreumatic oil. The combustion of oil is attended with much the same results as tallow. Composition candles, into the preparation of some of which arsenic enters, are peculiarly objectionable. Wax candles produce less injurious change in the air than any other form of artificial illumination. The wax melts only at a very high temperature; its decomposition and combustion take place at the same point; it burns much more completely, and gives rise to fewer volatile products. The most objectionable mode of illumination for private rooms is, undoubtedly, gas. From the combustion of this there results not only a large quantity of carbonic acid and watery vapour, but other very injurious products. In the first place, a large quantity of carbonaceous matter, which is evident from the blackness of ceilings in rooms where gas is used, and which, becoming inhaled, must of course irritate the air-tubes. Secondly, as shown by my friend Dr. Letheby, ammonia and fœtid tarry matter, the former of which leaves its traces in the injury it does to copper and brass fittings, the latter, in the saturation of the soil traversed by the pipes. Thirdly, as shown by the chemist just cited, bisulphuret of carbon, which, in burning, becomes converted into sulphurous acid, which, by the abstraction of more oxygen from air, becomes

sulphuric acid, or oil of vitriol. Dr. Letheby has found as much as 212 grains of this acid in 1000 cubic feet of gas; and he adduces ample evidence of its existence and action in the destruction of the covers of books in several large libraries; whence we can readily infer its injurious effects upon man when introduced into the lungs. Further, the elevation of temperature is much greater with gas than with any other mode of lighting. The combustion of gas, therefore, in a room, the air of which is not frequently renewed, is highly prejudicial, and even dangerous. After some suggestions for improvement in its manufacture and purification, Dr. Letheby concludes, that gas as now constituted should be "burnt outside the room or shop wherever it is practicable; and, when this is not the case, the products of combustion should be conveyed away by a special contrivance as speedily as possible; indeed, they ought not to be allowed to escape into the room at all."

When no effective renewal of the air of rooms that has been impaired by respiration and combustion is provided for, injurious physical consequences, varying in character and intensity, are the result. General uneasiness, headache, oppression, and faintness or giddiness are among the immediate symptoms—the fainting and hysterics

which are not uncommon in public assemblies and in churches that are close and overheated. It would appear, that habitual exposure to air thus rendered impure increases materially the tendency to consumption, and to various forms of scrofula in the growing and adult, and also the liability to the worst types of fever. The researches of Health Commissioners go to prove, that the 60,000 deaths that occur annually in England and Wales from consumption, are due more to bad ventilation than to our changeable climate; and that the mortality from this disease is among those who work in shops and factories, and inhabit the gloomy alleys and close courts of our poorer districts. M. Baudelocque considers that scrofula is due almost entirely to habitual exposure to impure air, and that even a few hours' sojourn each day in a vitiated atmosphere may induce it. Mr. Phillips, on the contrary, thinks that bad or insufficient food has more to do with this disease. Probably both causes are concerned in its production*.

There was something appalling in the revela-

* There can be nothing more injurious than the overcrowded condition of many parts of our large towns. Here we have confined air greatly deteriorated by the combined action of many pairs of lungs, to say nothing of deleterious emanations from the surface of individuals.

tions which were made respecting the habitations of human beings in this country, when sanitary reformers first began to bestir themselves. In 1844 there were 18,000 individuals in Manchester, and more than 25,000 in Liverpool, living, according to Dr. Duncan and others, in cellars, in many of which the floor was the bare earth; their height less than six feet; the door, the top of which was on a level with the street, being the only mode of access for air and light. In these cellars, darkness, dampness, dirt, and defective ventilation produced their combined influence on the wretched inmates, realizing a condition which renders it a flight of poetical fancy indeed to suppose that

> The inevitable morning
>   Finds them who in cellars be,
> And be sure the all-loving nature
>   Will smile in a factory.

Though the state of things so graphically described by Dr. Duncan, in his evidence before the House of Commons, no longer exists, this metropolis, and other large towns, still teem with human beings almost destitute as regards the necessaries of life, and demanding our active sympathy far more urgently than the benighted natives of Central Africa or the Fiji Islands.

But how, you will ask, are the several poisonous

emanations which are generated in our in-door domestic, or public life to be prevented from exercising their deleterious influence? Providence has furnished, and clearly indicated the means, in subjecting gaseous matters to laws, which every one should be made conversant with, in order that he may be able to act upon them.

One of these, the diffusion law, I had occasion to glance at in my last Lecture. It is one of those exceptions, however, to an otherwise general law, which indicates unmistakeable design, and is of such importance in regard to this branch of our subject, that I must again draw your attention to it.

The entire bulk of the atmosphere obeys the great law of gravitation, or of attraction towards the earth's surface or centre, and is consequently dense in proportion to its proximity thereto: the gases of which the air is composed, on the contrary, in common with other gases, obey a law opposite in its action, and known to chemists as the diffusion law. In accordance with this, when brought into contact, they become perfectly intermixed,—heavier gases ascending, and lighter ones descending, in opposition to their specific gravity, and in the face of other and apparently insurmountable obstacles. Impelled by this law, as I before observed, the different gases constituting

the atmosphere, instead of forming three distinct strata—the heavy carbonic acid below, the lighter oxygen in the middle, and still lighter nitrogen at the top,—are found to be ever, in all latitudes and altitudes, intimately blended in precisely the same proportions. That deadly poison carbonic acid, which is constantly being given out in the processes of combustion and animal life, and from other sources in the inorganic world, instead of lying in a dense stratum contiguous to the earth's surface, and rendering life impossible, is silently but effectually distributed through the atmosphere; other gases, equally injurious, are in like manner equally diffused, and, as it were, lost.

The action of this diffusion law is, however, not sufficiently rapid to meet the necessity of the case, viz. the immediate purification of the atmosphere. Providence, therefore, inexhaustible in resources, has brought another law into play, that of the expansion, and consequent diminished density, of gases under the influence of heat. This expansion of common air, under increase of temperature, is, as Dr. Arnott suggests, easily demonstrated by holding to the fire a bladder not quite full of air, and tied tightly, so as to prevent escape. The dilatation of the air within causes it immediately to become tense. Now, a given volume of air

thus expanded is of course lighter than the same volume of colder air, and will immediately rise to the surface of the latter. The air of a room, or that in contact with the earth's surface, is thus heated by convection, as it is termed,—by the lighter, warmed air being conveyed, or passing up through the heavier and cooler air, which descends to occupy its place; such interchange being continued until the entire mass is heated. This simple law, by which a gaseous fluid, rendered lighter by heat, rises through that which is heavier, and the rapidity with which it acts, ensures a constantly renewed supply of fresh air to breathing creatures. In obedience to this law, the poisonous air exhaled from the lungs of a man or other animal, being of the temperature of the body, and, therefore, in general, many degrees higher than the surrounding air, ascends far up into what Arnott happily terms the purifying laboratory of the atmosphere, while fresh air descends to meet his wants. As a result of this law, we have those great purifying agents of the general atmosphere, the winds; while the same law operates more quietly in supporting combustion of lights and fires, and thus effecting the ventilation and purification of our homes.

Let us see, however, how the law in question

operates in effecting the ventilation of rooms; for it is in reference to this point that we have now to consider it.

Most rooms in England are heated by means of an open fire-place, which is furnished with a chimney for carrying off the products of combustion. Now, what takes place under this arrangement? If the air of the chimney and that of the room be of the same temperature, no change will be effected. When, however, there is a brisk fire, the air above this in the chimney becomes heated, expands, rises, and is expelled; colder air from the room rushing in to take its place. This phænomenon is repeated as long as the fire is kept up, and a continued ascending current of air is thus maintained in the chimney, which carries with it carbonaceous particles, and the gaseous results of combustion. A portion of the warm air passes into, and ascends to the top of the room, inducing a series of ascents and descents, until the chamber is pretty equably warm; this result being brought about much sooner if there be a tolerable interval between the fire-place and opening of the chimney-flue. Under these circumstances, and when there is no special arrangement, fresh air will pass into the room by apertures left from badly fitting doors and windows. During seasons when a fire

is not needed, the air of the chimney may become colder and denser than that of the room: it consequently descends into this, while fresh air descends into the chimney from above. It is in this way that occasionally in summer-time the smoke from neighbouring chimneys finds its way into rooms that have been long without a fire.

But this is not the whole philosophy of chimneys. They do something more than allow the ascent of hot air: they quicken it, and they do this, simply by keeping a long column of it together,—the rapidity of ascent bearing a direct relation to the length of the column, or, in other words, the draught of a chimney being in proportion to its height*.

Now, the arrangement just considered might be supposed to meet all our requirements in regard to change of air; but, in effecting this, we have to avoid insidious currents—draughts—which are almost as serious in their consequences as air charged with the poisonous products of respiration and combustion; while, at the same time, they are a very prominent feature of rooms as constructed in this country. In these, ventilation is effected by the entrance of cold air from crevices in window- and door-fittings, which passes from these directly to the fire-place, and up the chim-

* Arnott's 'Elements of Physics.'

ney-flue, and affects only the lower stratum of air in the room; the legs being favoured with a continuous cold *douche* as the air rushes towards the flue, while the head, and the mouth, through which respiration is effected, are exposed to the unshifting stratum in the upper part of the room. The effect of having the different parts of the body thus exposed to different temperatures, is, to engender coughs, colds, and rheumatism; and, in the delicate, very often to lay the foundation of consumption. It also induces a forgetfulness of danger arising from an opposite state of things, and causes the minds of people to be so haunted with fear of the ailments alluded to, that, on settling themselves down — making themselves comfortable, as they term it—for the winter evening, every effort is exerted, by means of closed shutters, drawn curtains, and shut doors, to exclude the possible renewal of air poisoned by the action of human lungs, and the combustion of lights and fires. The injurious consequences of thus inhaling, night after night, an impure air, exhibit themselves in various ways; depression of spirits and disinclination for intellectual exertion being a frequent and marked result. The exclamation, "I don't feel in the humour for work to-night," from one or other of a party thus inclosed, may frequently be heard.

Now, by attention to the laws which I have noticed, we need neither be chilled by draughts nor poisoned by impure air. Seeing that heated air, being lighter, has a tendency to rise, and that carbonic acid, though much heavier than the atmosphere, does not gravitate at the bottom of the apartment, but, in obedience to the diffusion law, has a tendency to disperse, it follows that one great principle in effective ventilation is to ensure a constant renewal of the upper stratum of the air. This may be done by a ventilator placed near the ceiling, and communicating either with a special ventilating flue, or with the ordinary chimney. In the latter case, when there is a brisk fire, the draught from this will materially assist our mechanical arrangement. The ventilator is furnished with a valve, which opposes the recoil of air and smoke that would otherwise occasionally take place. Generally, this is the only arrangement adopted; the cold air that enters by imperfectly fitting doors and windows being sufficient for the supply.

But air thus introduced comes, as I said, in the objectionable form of draughts, and imparts a sensation of cold to the parts of the body that may be exposed to it. Hence, effective arrangements should embrace another aperture, or series of apertures, on a lower level than the first, for

the ingress of air. The skirting or door may be made the medium for these; and they should be small, so that the air may enter in a divided state, and in sufficient but not excessive quantity. The large open chimneys, still so frequently met with in this country, carry off all heat from the fire, cause great consumption of fuel, and keep up a perpetual draught in the room, by the great rapidity with which they carry off the air contained in it. No doubt the practice which prevails abroad of heating rooms by stoves, the combustion of fuel in which is fed by air from without, and which merely transmit their warmth to, but do not communicate with the room, has its advantages; enabling the inmates of a room so heated to sit in any part of it, without being annoyed by the play of air between the door and fire-place; the necessary ventilation being effected by apertures in the upper part of the room*. Attention, however, to the suggestions I have made, will enable us to retain the open fire-place, which is so closely associated with an Englishman's feelings, and which certainly exerts a cheering influence upon the mind. Perforated zinc plates and glass are now generally used for ventilation in

* Those who are interested in the subject of ventilation and warmth would do well to read Dr. Arnott's recent work, entitled, "The Smokeless Fire-place," &c.

workshops. Where gas is used, a ventilator placed in the ceiling, immediately above the lamps, is the most effective means of carrying off the impure products.

The importance of effectively ventilating sleeping apartments, in which so large a portion of human life is passed, cannot be over-estimated. Strict cleanliness in all that relates to such apartments; a thorough change of air during the day, effected by open doors and windows; the prevention at night of any undue confinement or vitiation of the air by closely-drawn curtains and large fires, are indications that must be closely attended to. Of the necessity of good ventilation in all buildings in which numbers of human beings are habitually or periodically associated,—as in workshops, factories, schools, hospitals, churches, theatres, &c.—there can be no doubt; but it is quite evident, from the various ways in which the ingenuity of philosophers has been exercised upon the subject, that no little difficulty attends the realization. Perforated floors and ceilings, revolving wheels, tubes furnished with valves, modified bellows apparatus, air exhausters, chemical action, have each had their turn and short-lived triumph, until any new attempt has been considered fair matter for ridicule.

Imperfectly as ventilation is yet realized in

many of our public institutions, it must be allowed that the air within them is far more respirable than it was formerly. During an Old Bailey Session, held in the middle of the last century, the lord mayor, two judges, an alderman, and some other individuals died of typhus fever, caused by the putrid emanations from the prisoners who were brought in for trial. Such was the condition of our prisons at that time, and until Howard's energetic philanthropy effected a change.

The Great Exhibition building of 1851 afforded a striking instance of the importance of ventilation. From the time of its opening to June 10th, the weather had been mild; on that day the thermometer rose to above the average, and continued to rise till the 26th, when the mean temperature was 78° 6′, two degrees above summer heat. At 4 P.M. of this day, the thermometer, placed in the north-east corner of the gallery, registered 97°. "The public could not stand this, even to witness the grandest sight that man could produce; 'the force of nature could no farther go,' for the air was not only hot, but vitiated. Women fainted right out, and men declared the heat intolerable." After some consultation, the glass ends of the building at the entrance were, on the 2nd of July, removed, and

the consequence was a reduction of temperature from 79° to 66°. Still the air in the galleries was vitiated and unfit for respiration; its temperature being four degrees or more above that of the main average. The public felt oppressed and uncomfortable, and the policemen and sappers are said to have suffered in health. To remedy this, on July 7th glazed arches at different parts of the galleries were removed; the result being, an effective renewal of the air, and equalization of temperature in the avenues and galleries. "Fifty thousand pairs of lungs enjoyed daily the constant current of fresh air. This kept the multitude below the grumbling point till the 19th July, when Saturday, with its 5*s.* admission, brought a thin attendance. The first sudden transition from heat to cold was instantly felt throughout the building. Down went Fahrenheit to 59°, and therefore called for measures in an opposite direction, and accordingly up went the louvres and ventilators, till the temperature was again adjusted. Thus man has made Nature, to a great extent, obedient to his will, in the very difficult matter of ventilation in an unwieldy building 1850 feet long*."

Time will not allow me to dwell longer upon this part of my subject. I can but urge the im-

* Morning Herald, Sept. 18th, 1851.

portance of attending to principles which are indispensable to health, and must leave the question of how they are to be carried out to minds of more mechanical turn than mine. I hasten to consider the causes which tend to vitiate the air external to our dwellings,—the operation of which is illustrated on a large scale in our towns and cities.

London still exhibits traces of the quaint and picturesque, but unhealthy construction of its streets and houses in days of yore; and in many continental towns, long narrow streets, with opposite houses in close contact, may still be seen. We may readily imagine how such an arrangement, by preventing the access of light and the free escape of noxious vapours, must have fostered and aggravated fevers and various epidemic disorders. Add to this arrangement of the streets and peculiar construction of the houses, the entire absence of sewerage, the deficient water supply, and the existence of other intolerable nuisances, and we may conceive what must formerly have been the sanitary condition of a large town. Hufeland, who wrote upon health about sixty years back, says: "Let whoever can, avoid residence in large towns. They are the open graves of mankind, and not only in a physical, but also in a moral sense. Especially let him shun those

where many human beings are packed together in a small area, and live rather over than by the side of each other, where the houses are high, the streets narrow, the open spaces few, the trees few, where there are sundry closed courts and cul-de-sacs, and no police to look after the cleansing of the streets. Even in smaller towns, where perhaps the streets are somewhat narrow, a dwelling outside the town is preferable, and, at any rate, it is a duty, every day, quite to escape from the atmosphere of the town for half-an-hour or an hour, in order once to breathe a fresh air."

Although on the continent, and still more in this country, considerable progress has been made in the sanitary arrangements of large towns, very much remains to be effected, and it will therefore be quite pertinent to our subject to indicate the several causes of atmospheric vitiation which still, in greater or less degree, prevail even in the streets of this metropolis. One cause affecting the air external to, as well as that within our dwellings, is an entire absence or imperfect system of private drainage and general sewerage. When the waste fluids, the débris of animal and vegetable substances used as food, and the ordinary refuse which are the unavoidable results of life, are not effectually cleared away, they decompose, evolve poisonous

gases and emanations, and become pregnant with destruction. You are all, doubtless, aware, how chloroform, ether, and turpentine, when mixed with common air and taken into the lungs in respiration, become absorbed into the blood, and produce rapidly their specific effects upon the system. It is thus, in all probability, that the invisible and impalpable but destructive emanations from individuals suffering from fever and other disorders, become inhaled by and infect others who are brought into contact with them. Exactly in the same way, also, do the noxious products of decomposing animal and vegetable matter with which the air may be charged, produce their effect upon the human frame; being, there is every reason to suppose, directly absorbed by the blood circulating in the minute vessels of the air-cells, and by it carried over the system. The rapidity, intensity, and distinctive character of the action of such gaseous products, depend upon their nature and the degree to which the air is charged with them. The principal gas given out by stagnant refuse matter is sulphuretted hydrogen, a deadly poison, one part of which, diluted with 800 parts of atmospheric air, is sufficient to kill a dog, while one part diffused through 1500 parts of air was proved by experiment to be rapidly fatal to small birds. The men who have been employed

in clearing out places where this and other gases existed in a concentrated form, have almost instantly fallen victims; while, in other cases, where this gas has been more diluted with air, its inhalation has caused nausea, faintness, delirium, and insensibility. The frequent consequences of exposure to these poisonous agents are violent diarrhœa and irritability of stomach, followed by excessive prostration, symptoms, in short, resembling those of cholera; while in localities thus rendered impure, fever is most frequent and virulent.

Cesspools, stables, cow-sheds, pigsties, stagnant ditches, mud, dung or dust heaps, are all so many sources of foul emanations, and should not be suffered to remain in juxtaposition with human habitations. Those manufactories also, which vitiate the air by gaseous or other emanations, should be removed from the vicinity of dwellings to spots on the outskirts of towns.

To say nothing of the interruption to traffic and the danger to pedestrians from troops of horned cattle constantly passing through the streets, the relics of the two or three million animals annually brought to the London market are a prolific source of atmospheric impurity. As far as the metropolis is concerned, this gigantic nuisance is condemned, and it will therefore be futile to spend more words about it.

A river, as it flows through the heart of a large town, should form no part of the general sewerage system of such town. The offcast impurities of London have, however, for ages, been discharged into the Thames. A portion of these may perhaps be constantly carried down with the tide; but a still larger part is deposited in the bed, or permanently mixed up with the waters of the river. It is calculated by Mr. Glaisher, that from the surface of that portion of the Thames flowing through London, 4,170,000 gallons of water are daily given off in the form of vapour, which passes into, and becomes intimately blended with, the atmosphere. Now, it is evident, that with this vapour there must also pass off noxious emanations from the foul matters disgorged into the river by the sewers; while some of the more solid refuse, being left exposed at low-tide on the mud immediately below the inhabited banks, putrifies under the influence of the noon-day sun, and infects the atmosphere.

Far be it from me to speak slightingly of that affection which clings even around the mortal remains of a departed relative or friend, and which has its source in the human heart. Such affection exhibits itself among people of every race, and in every stage of progress from darkest barbarism to highest civilization. The reply of the

Canadian Indians, when they were urged to emigrate, expresses the almost instinctive tenacity of such attachment: "What!" they replied, "shall we say to the bones of our forefathers, Arise, and go with us into a foreign land?" It is unnecessary for me to trace out the evidences of this attachment in the practices of different races, either at the present day or in more ancient times. It is sufficient to remark, that this feeling, and the desire of being buried in the old ancestral vault or family grave, by the side of those who were loved and respected when in life, account for such lingering attachment to intramural burial as may still exist. But, of the injurious effects of crowding together the dead in the midst of the living, there can be no doubt. The chemistry of death—and I am speaking of physical life and death—is directly antagonistic to that of life; it is only after changes have been effected in a circle, as it were, that a new being can be said chemically to spring out of the ashes of another. I do not purpose entering into any details to establish the point; but, in considering the causes that vitiate the air, and affect the due performance of the chemistry of respiration, it would be impossible to pass over this. Without dwelling upon repulsive minutiæ, it is sufficient to observe, that the gases given out from the body, when in pro-

cess of decomposition, are most virulent in their nature, and cause different symptoms, according to the degree to which the air is charged with them,—faintness, nausea, diarrhœa, giddiness, insensibility, and even death; that they not only become diffused through the air we breathe, but also absorbed from the soil by the water that we drink, or use for domestic purposes; and that thus they increase tenfold the fatality of the passing epidemic. The more civilized nations of antiquity — the Egyptians, Hebrews, Greeks, and Romans—associated with their respect for the dead an enlightened consideration for the living; and where they did not practise extramural burial, had recourse to embalming or cremation. The early Christians followed in the steps of the more advanced of the ancients. It was only in comparatively modern times that interment in the interior of large towns became general, and, by degrees, so gigantic a nuisance, that the attention of legislators and philanthropists became directed to its removal. In France and other continental countries, it has long been discountenanced. The discontinuance of the practice, which is now being tardily effected in England, is due entirely to the earnest devotion to the subject, by Mr. G. A. Walker, of mind, time, and means; and I gladly avail myself of this occasion

to testify to the services which that gentleman has, in this respect, rendered to the community.

I have thus glanced at different sources of atmospheric impurity within and external to our dwellings; I have shown how the gaseous emanations from these, when diffused through the air, become inhaled, and that when absorbed, "the life of all the blood is touched corruptibly," and they become the fruitful promoters of disease, and the close allies of pestilence. The great physical laws by which Providence governs the world, and among them those which regulate the health of man, are comprehensive in their operation, and capable of being appreciated by all. Those who, cognisant of their actions and indications, neglect to apply all the means in their power to their realization, who allow poisons to be inhaled with the breath of life, are scarcely less culpable than if they were to mix arsenic with food intended for their own use or that of others, and may be said literally to court disease and death in themselves, and to countenance the wholesale destruction of their fellow-creatures.

LECTURE III.

In this Lecture I shall glance, in the first place, at certain causes by which the air we breathe is either temporarily, or, in some cases and localities, permanently impaired for the purposes of life.

Mysterious in their approach and nature, those unseen agencies, by which, from time to time in the world's history, whole communities have been smitten down with disease and death, have been regarded by man, especially in a state of barbarism, as the lightnings of wrath which, in old illustrations of the Bible, or of Paradise Lost, the Deity is represented as darting forth from his hand among the criminal and guilty. The superstitious of every age, not caring, or not daring, to investigate, have fallen back on supernatural causes to account for the severe visitations of pestilence, in its various forms, with which mankind have at different periods been afflicted; malignant planetary conjunctions or angry gods satisfying the credulous in former days; punishment for national crimes, which have not been very clearly defined, forming the staple com-

modity of explanation in a later and more enlightened age.

Let us glance cursorily at the results which have followed the cautious philosophical investigations of different inquirers in the last few years, both as to the nature and manifestations of the pestilence which comes most home to us—the cholera,—and, if we at last come to the conclusion that it and other plagues are to be regarded as Divine visitations, it will be because we can distinctly indicate the offences which have called down the judgment.

Originating in the East, on the banks of the Ganges, cholera for a time hovered about the region of its birth, until, after some years, it began to travel thence, over different regions of the earth, tracking out a peculiar and irregular course; not being wafted on the wings of the wind, but, on the contrary, advancing in the teeth of these and other influences; not at first, like other epidemics, sweeping, flood-like, over districts, but taking a zigzag course, and appearing at uncertain intervals. Usually it seemed to propagate itself through the air, appearing at last suddenly in certain parts, though its approach had long been expected; sometimes it seemed as though a person or persons not affected by it, carried it from one locality to another; and, occa-

sionally, the way in which individuals were seized who had been the attendants on other victims, left room for questioning how far it was contagious. After the most careful investigations, which have been conducted by men of intelligent and unbiased minds, during the three visitations with which this country has been afflicted, it must be admitted that we are still entirely in the dark as to the real nature or essence of the poison on which it depends. It does not seem referable to any peculiar state of weather,—the summer in which it first raged in Europe being remarkably hot and dry, changeable weather attending its second visitation, and a dry, fine summer the last. Though generally exhibiting itself through the summer and autumn, in some districts it has raged at the commencement of winter. Gradually increasing in severity, and in the number of victims to it, when once it has attained a height and begins to decline, its further decline seems certain; no matter if favourable circumstances exist, which one might think would induce it to linger in any particular district. Prout, Andraud, Quetelet, Glaisher, and other inquirers, from the fact that thunder storms, and the restoration of electric fluid to the air, were coincident with the rapid decline of the disease, and, also, from actual experiments, imagined that the epidemic was due to

a deficiency of electricity in the air; but this may have been merely an attendant circumstance. Cowdell and others—and this notion has been recently revived—fancied that cholera was due to cellular fungous bodies, visible only under high magnifying power, which they detected in the atmosphere, and in the excretions of individuals suffering from the malady. These particles were supposed, when taken into the system, to multiply themselves by a sort of fermentation, and so produce the disease. Hence the notion of eliminating or driving out the poison from the system, and the castor oil and analogous treatment which arose out of it. But the fungous bodies were shown by Mr. Busk to be the same as are introduced into the system in vegetables used as food; and, were it not so, it would have been as rational to have regarded them as a symptom of the malady as its cause. Moreover, it is well known to medical men, that under the depressed vitality attending fevers and other affections, similar fungous bodies take possession of the frame. Other inquirers have fancied that the cause of cholera was to be detected in organic bodies, similar to those just noticed, and which are diffused, to a greater or less extent, through the water supplied to the inhabitants of large towns. Another theory has reference to the discovery of Professor Schön-

bein, of an ingredient met with in variable quantity in the air, and called by him ozone. This matter consists of the elementary principles of water, oxygen and hydrogen, with twice as much oxygen. From the circumstance that an atmosphere artificially charged with ozone immediately deprives the most putrid solid or fluid bodies of all disagreeable smell, and that the gas given out from ordinary refuse, sulphuretted hydrogen, is instantly decomposed by it, he regards it as the great agent employed to convert the deleterious exhalations which the air receives into innocuous matter. This theory Professor Schönbein associated with the electrical by showing that electricity was necessary to the development of ozone, and that during the cholera visitation, when there was a deficiency of electricity, an appreciable quantity of ozone could not be detected in the air of London. According to these views, this substance is the great purifier of the atmosphere, and cholera is the consequence of its absence. Those who adopted this theory did not hesitate to apply it. The immunity enjoyed by certain towns was explained by the ozone given out in manufacturing processes carried on in them. A workhouse at the east end of London, but few of whose inmates fell victims, was supposed to owe its escape to the purifying influence of ozone evolved from a dust-

heap in front. The said dust-heap has since been condemned, and the ozone theory, however plausible, does not seem to touch the subtle essence of cholera. If, however, investigators have failed in throwing light upon the cause of cholera, their inquiries as to its manifestation, course, and the facts connected with its history, have resulted in a more satisfactory conclusion; in the all-important conclusion, in short, that its virulence, fatality, and the extent of the ravages it may commit, are affected by causes over which man has complete control. Neglect of the conditions necessary to health, in the individual or community, is found to be the most predisposing cause of such diseases. The squalid, the badly or imperfectly fed, and especially the intemperate, were those who most readily fell victims to the cholera, which committed its most fearful devastation in low, damp, ill-drained districts; in crowded, badly-ventilated quarters; in the vicinity of foul sewers, stagnant ditches, crowded burial-grounds, and other sources of impurity. Were I to select one cause as predisposing more powerfully to this disease than any other, it would be a faulty condition or absence of private drainage or general sewerage. The gas given out from ordinary refuse matter is, as I stated in my last Lecture, sulphuretted hydrogen, a deadly poison, which, even

when largely diluted with atmospheric air, induces symptoms resembling those which frequently usher in the cholera. The history of the epidemic shows unmistakeably how much influence is exerted by this cause; for localities in which it raged during its first visitation, and which were subsequently well drained and purified, were found almost to escape when it made its second appearance amongst us.

Some intelligent inquirers into the causes of this epidemic, dissatisfied with the various hypotheses regarding its nature, and noticing the constant connexion between its manifestation and local atmospheric impurity, have supposed that its origin may be traced to some such local sources. This view receives confirmation from the fact, that in the portion of India where the disease first manifested itself, viz. on the banks of the Ganges, the air is constantly poisoned by emanations from the large quantity of mud and filth which is at one period of the year mixed with the water of the river, and at other periods, when the river has fallen, lies festering on the banks. The Ganges, moreover, is the cemetery of the native tribes; and dead bodies, in a decomposing state, are ever tainting its waters, and the air in contact with them. Be this as it may, my own experience of its course, during different visitations, leads

me to the conviction, that cholera may be regarded as a chastisement for neglect of laws which Providence has wisely imposed as the present conditions of our health and well-being, and by inattention to which we directly invoke the judgment of Heaven. As far as experience has taught us, the disease has invariably been diminished in severity in districts where the laws of health, as affecting communities, have been carried out; and those individuals living in such favoured districts have enjoyed almost complete immunity, who have realized in themselves the indications of health-laws in diet, exercise, cleanliness, and, above all, in freedom from the prostrating and paralysing influence of fear,—who have, in short, exhibited unflinching physical courage, backed by the still higher confidence or moral courage which results from the effective discharge of duty, and the consequence of this, a good conscience.

Malaria, again, is one of those poisonous and subtle agencies which escapes the searching analysis of the philosopher, but which, in its history, conveys to us most instructive lessons. This poison consists in peculiar emanations from the earth's surface, called, from their frequent occurrence in marshy places, marsh miasmata. They are supposed to be gaseous in their character; but are not, however, palpable to sight or smell, or to

be detected by chemical tests. Some persons, from the circumstance that they keep to the surface of the earth, and from the way in which they are intercepted by certain substances, imagined that they were ponderous. Dr. Croly, in describing a district infected by this poison, speaks of the "marshy border, the sickly vegetation of the shore, the leaden colour which even the sky above it wears, tinged by its sepulchral atmosphere." This description would not always apply; for the late Dr. Stanger, who accompanied the expedition up the Niger, assured me that he had never known a brighter sky, or clearer, more buoyant atmosphere, than that through which he passed; yet the men were stricken down with the most fatal form of remittent fever. Extreme heat and moisture, and decomposing vegetable matter, have been considered necessary to its production; but it has shown itself on perfectly level, sandy plains, utterly devoid of vegetation, and which were not always humid. Ague in this country, and, in warm climates, fatal remittent fevers, are among the more immediate effects of this poison; the inhabitants of districts where it habitually prevails being ill-developed, sickly in aspect, and deficient in bodily and mental vigour.

The most important consideration is, that this poison is in great degree under our control. In

several countries of Europe, districts have been entirely freed from it, by effective land drainage and cultivation, as in some parts on our eastern coast. Ague was once very common and fatal in London. James I. and Cromwell are said to have died of it; the sanitary condition of the city, and the dampness which then characterized its less elevated quarters, accounting for its presence. Now, if met with in the metropolis, the disease has generally been contracted elsewhere. On the other hand, districts, as in Italy, which when inhabited and cultivated, were perfectly free from malaria, on becoming waste and desolate, have again generated it.

The Great Plague, the nature of which is wrapped in the same mystery as that of the poisons I have considered, tells the same tale. In its visitations it found a congenial atmosphere in the filthy and neglected condition of the metropolis, and its ravages far exceeded those of any subsequent desolating influence. The Great Fire took place, swept away the worst quarters of London, purified the air, and the plague returned no more.

There are other atmospheric conditions, bearing upon human respiration, which I must not altogether pass over. Among these is its hygrometric state, or the degree to which it is charged with watery vapour. Of this it always contains a certain

amount, varying from the 60th to 200th of the bulk of the atmosphere, the quantity being greater in hot climates and seasons than in cold. A due admixture of this watery vapour in the atmosphere is essential to man's health and even his existence. Watery fluids constitute about four-fifths of the entire weight of the human body. Water is continually being given off by evaporation from the lungs and skin, and if the air inhaled were entirely free from it, thoroughly dry, the fluids necessary to the fulness and elasticity of the tissues would gradually be breathed out, and his frame would wither and shrivel up. Thirst, fever, and the fatal consequences which attend exposure to the simoom and the hot winds of the desert, result from their deficiency in watery vapour. Similar consequences, only of a much less serious character, are experienced even in this country, during the long prevalence of strong winds from the east.

An excess of watery vapour in the atmosphere is also prejudicial. A warm, humid air diminishes the tone of the system, and causes a sense of oppression, by preventing the free perspiratory action of the skin; the watery secretion from which cannot pass off into an atmosphere already charged with moisture. A cold humid air also arrests the action of the skin, and by carrying off the heat of

the body, causes a penetrating sensation of chilliness, and induces coughs, colds, and rheumatism. There are other ways in which an atmosphere highly charged with moisture operates prejudicially to health, viz. in the greater readiness with which substances capable of volatilization assume the gaseous form in it, the rapidity with which it absorbs gases, and the way in which it holds in suspension the poisonous essences of malaria and epidemics. This action of a very humid air is familiarly illustrated in the repulsive odour of the air contiguous to stagnant pools and ditches during damp weather, or, more pleasingly, in the fragrance of the rose and other flowers after a shower. From the rapidity with which the air in streets becomes charged with unpleasant odours on rain ensuing after a long period of summer drought, it would seem that a warm humid air not only absorbs noxious gases and emanations, but that it favours the decomposition of organic particles. Such a state of weather, moreover, by relaxing the human frame, predisposes it to the injurious effects of noxious influences.

The easy and effective discharge of the function of respiration is, of course, influenced by the relative density of the air inhaled. The atmosphere is, as is well known, dense in proportion to its proximity to the earth's centre. At the surface

of the earth, the sea-level, it presses upon everything with a force equal to fifteen pounds on the square inch; so that the body of an adult man sustains a pressure of 32,000 or 33,000 pounds. We are not ordinarily sensible of this, because the pressure is equally distributed over every part of the body, and the cavities, organs and tissues of the body are filled with resisting elastic fluids or air; but by creating a vacuum over any part, as in the application of the cupping-glass, our flesh rises to fill the vacancy, and we gain some idea of the immense weight bearing upon us. If we descend a mine, or go down under water in a diving-bell, the pressure is found to increase with the depth; on the other hand, as we ascend a mountain, the pressure is found gradually to decrease, in consequence of the diminution of the superincumbent weight of air. The air itself too, as the pressure is diminished, expands with the elasticity of a spring, or becomes more rarefied, as it is termed; dilating to double the bulk when the pressure is diminished by one half. The more rarefied the air is, other conditions being the same, the colder it is. This may be easily understood; for if a given quantity of air with a certain temperature be suddenly dilated to double its volume, the heat will be distributed over twice as large a space, and be sensibly diminished by one half in any point

of such air. The degree of density of air which obtains at the earth's surface, seems the best adapted for the well-being of man; maintaining the temperature at a fair average standard, preserving the compactness and tone of different parts of the body by its equable pressure, preventing undue evaporation from the skin and lungs, and acting in harmonious relation with the function of respiration. There can be no difficulty in understanding the distress experienced by travellers or by aeronauts on ascending to very high elevations. Humboldt ascended Chimborazo to a height of 19,000 feet, and Gay Lussac, in a balloon, attained an elevation of 23,000 feet above the sea-level. They and other philosophers have graphically described the sufferings experienced on reaching very great elevations. These sufferings were due, not to any difference in the actual composition of the air, but to its extreme rarity. One effect of this is, that the usual quantity of oxygen is spread over a larger space, and less, consequently, is taken in with each inspiration. Hence, the great difficulty of breathing, and the increased rapidity and depth of the respiratory movements in order to inhale a sufficient quantity of oxygen. Another effect is due to the removal from the body of a considerable portion of the weight which usually bears upon it, and the

consequent relaxation of the blood-vessels, &c. of the surface. Hence the injected state of the eyes, and the bleeding from the nose and gums which are frequently experienced by those who have attempted to cross lofty mountains. To both these causes may be attributed the giddiness, oppression, fainting or unconsciousness, and other symptoms, with which different travellers have been affected in very high regions. Notwithstanding these facts, it is found that man, after a time, becomes habituated to these high elevations; and this proves that he was destined to subdue and inhabit every portion of the globe. Nearly all the inhabited portion of the ancient empire of Peru was situated at an elevation varying from 6000 to 9000 feet above the level of the sea. Potosi on the Andes is 13,000 feet above the sea-level, and Antisana, the highest inhabited spot in the world, is 13,500. Darwin says that strangers do not become used to the air of Potosi for a year or more. Those who are brought up in these districts from childhood experience no difficulty, and it is evident that they must absorb as much oxygen as races living on a level with the sea, or they could not be as healthy and vigorous as they are. They would seem to overcome the difficulty by their highly developed chests and lungs, by which they are enabled at each inspiration to in-

hale a larger quantity of air. M. D'Orbigny says that the Quichuas have square shoulders, and a broad, expanded, highly arched chest, which is longer than usual, and gives increased size to the trunk. "Many considerations," he says, "have led us to attribute this to the influence of the elevated regions in which they live, and to the modifications occasioned by the extreme expansion of the air. The plateaux which they inhabit are comprised between the limits of 7500 to 15,000 feet above the level of the sea: there the air is so rarefied, that a larger quantity must be inhaled at each inspiration than at the level of the ocean. The lungs require, in consequence of their great requisite volume, and of their greater dilatation in breathing, a cavity larger than in lower regions. This cavity receives from infancy, and during the time of its growth, a great development entirely independent of that of other parts."

With persons of vigorous constitution, the "fresh-flowing," dry, bracing air of the hill-top or mountain-side is conducive to health. The very necessity, arising out of the diminished density of the air, which involves an increased energy of the respiratory movements, also, through these, promotes the activity with which other functions are discharged, and determines the muscularity, hardiness, and vigorous tone of mind and body

which distinguish the mountaineer from the inhabitant of the lowland and plain.

Average temperature, the humidity, density, and general purity of the atmosphere, combine with other conditions to form what is called climate; which, in its various bearings, is a subject of such vast extent, that to dwell upon it here would be quite out of the question. There are, however, one or two points connected with the subject, to which I must direct your attention. Locality, which is a sort of climate within a climate, and which embraces aspect, soil, and other local influences, exerts an important bearing upon the question of healthy respiration. The local circumstances which exert an influence in large towns have already been noticed. Those who live in the country, should, in the selection of a residence, consider well natural conditions. A sufficient elevation should be chosen, to allow of natural drainage; and humid, impervious soils should be avoided. Bodies of stagnant water, whether in the form of pools, ponds, or ditches, should not be too close to the dwelling; and thickly planted shrubberies and trees, in immediate propinquity, are especially objectionable, as being direct sources of humidity at all times, of noxious emanations during the decay of their foliage, and from their excluding light and preventing the free circulation of the air.

Periodical change of air, either for the preservation of health, or as a remedial measure, is of the highest importance. That people are not insensible to this is proved by the comparatively deserted state of the metropolis and its suburbs during a period of every year. Even those who habitually reside in the country may derive benefit by transition from one part to another, from the interior to the sea-coast, or the contrary. For the inhabitant of the town, however, frequent excursions into the country for the day or a portion of it, or a more protracted sojourn once in every year, is especially desirable. When we consider the various causes which, even under the best sanitary arrangements, vitiate the air in our large towns; when we also reflect upon the comparative deficiency of light, from the narrowness of streets, or from the air being charged with smoke, we can understand the advantage of a periodical change, not to country towns whose sanitary condition is worse, or to undrained swamps or marshes, but to the pure, renovating air of districts where all the natural conditions of existence are fully realized. The cares and anxieties of business, the impossibility that the denizen of the town often experiences of obtaining the necessary degree of exercise, and the artificial character of his relaxations, are further considerations in fa-

vour of such a change. To the man in tolerable health, it matters little whither he may wend his steps. The sea-side has this advantage over most inland districts, that the air there is purer than elsewhere, less heated in summer, milder in winter, and, from the circumstance that it is generally charged with saline particles, more bracing. The inhalation of pure and free air is, as M. Lévy observes, a physiological necessity; it is only in such that the function of breathing is carried on with the requisite force and fulness. In my last Lecture I showed that exercise powerfully affects respiration. I may now remark, that respiration, in its turn, materially influences muscular movement; a due supply of arterial blood being indispensable to the energetic action of muscles. The movements of respiration also directly act upon the cavity in which the organs of digestion are contained, stimulate these, and increase the digestive powers; hence the increased appetite and easy digestion usually enjoyed in a pure, bracing air. Periodical change of air, coupled with effective exercise, also enables the system to throw off the tendency to disease, and fortifies it against malarious influences. Looking at all these advantages, we may, I think, conclude with M. Lévy, that—"In general the atmosphere is the field of life; the dwelling answers to the require-

ments of civilization rather than to the exigencies of nature; it should serve only to shelter man periodically and for a while; if he makes his fixed quarters in it, he alters the essential conditions of organic life."

For the benefit of the poorer inhabitants of large towns, who are unable to enjoy occasional recreation in the country, public walks, parks, and winter gardens, in which during their leisure hours they may enjoy exercise and inhale a comparatively fresh air, are of essential importance. I know of nothing, indeed, more calculated to gladden the heart than the spectacle presented on holidays in the parks and other districts in the vicinity of the metropolis. Goethe, in his Faust, has given a graphic picture of the motley crowd passing on Easter day out of the dark gate of the city into the open campaign, having escaped from the pressure of gables and roofs, from the gloomy chambers of their wretched abodes and the yoke of their daily toil, into the free air and the light, to sun themselves, and, as he happily expresses it, celebrate their own resurrection.

Change of air can scarcely be over-estimated as a remedial measure in determining healthy action, and restoring vigour to the shattered frame of the convalescent. The influence which nature exercises upon the mind must also be taken into

account. Our own country affords a variety of climate, amply adapted for the effective restoration of the convalescent from most diseases. Some affections are, however, incurable; and for the alleviation of these, and the cure of some others, an equable mildness of climate is required throughout the year, which can only be met with in foreign countries. A protracted residence in these is, however, beyond the means of most people. Hence the project of establishing buildings, either independent of, or in connexion with, our large hospitals, in which, patients, while taking exercise, may enjoy some of the beauties of nature, and be in an atmosphere best suited to the complaint under which they may be suffering. And here I must make you acquainted with the precise meaning of terms. The word *sanitary* is derived from a Latin noun, *sanitas*, health, and signifies anything bearing upon this; a *sanitarium* being a place devoted to the maintenance of health, as the Crystal Palace may be considered. *Sanatory* is derived from *sano*, to heal, and has reference to curative measures for disease; a *sanatorium* being, therefore, a building devoted to the cure or alleviation of diseases. Now, medical men have long felt the want of sanatoria, in which they might imitate the climate of any country, and adapt such to the necessities of their patients.

Dr. Beddoes and one or two other medical men, in the early part of this century, paid particular attention to the maintenance of equable temperature in the rooms of consumptive patients, and but imperfectly carried out their designs by means of German stoves, and what was then known of the principles of ventilation. Dr. Arnott also, in his 'Elements of Physics,' published more than twenty years ago, describes a very ingenious contrivance for the same purpose. The most satisfactory and philosophical suggestion for the realization of artificial climates, emanated from Mr. Ward. This botanist, well known as the inventor of the closely-glazed cases, having, in these, successfully grown in crowded towns plants of extreme delicacy, was led to entertain the conviction that a modification of the same method might be beneficially applied to man. His views were first brought before the public in a lecture delivered by Professor Faraday at the Royal Institution in April 1838, and were further expounded in the first edition of his work, 'The Growth of Plants, &c.', published in 1842. "It cannot be denied," he there says, "that in a pure and properly regulated atmosphere, we possess a remedial means of the highest order for many of the ills that flesh is heir to; and every medical man well knows by painful experience, how numerous

are the diseases which, setting at nought his skill and his remedies, would yield at once to the renovating influence of pure air. The difficulty to be overcome would be the removal or neutralization of the carbonic acid given out by animals; but this, in the present state of science, could be easily effected, either by ventilators, or by the growth of plants in connexion with the air of the room, so that the animal and vegetable respirations might counterbalance each other. Among the diseases incident to man, which would be most materially benefited by pure air, I shall allude only to two, viz. measles and consumption." To Sir J. Paxton belongs the credit of having first attempted to realize a sanatorium upon the principles thus enunciated by Mr. Ward.

I cannot better conclude my subject, and, at the same time, impress upon your minds its vital importance, than by taking a rapid review of the different laws and agencies by which the atmosphere is maintained in a state of purity, and consequent fitness for the respiration of animals and man.

Among the provisions by which the constant purity of the air which we breathe is maintained, the *diffusion law*, from its immediate and rapid action, occupies a prominent place. Its nature

and operation have been already illustrated in the preceding Lectures.

Not less important is the law, to which I also directed your attention in the second Lecture, of the expansion of common air and other gases under the influence of heat, their consequent diminished specific gravity, and the currents and changes of air thus induced. I showed you the operation of this law in the heating and ventilation of rooms. In the great body of the atmosphere, change is effected in very much the same way. The air in contact with the earth's surface, becoming expanded by the heat radiating from the earth, is rarefied, as chemists term it,—rendered lighter than the surrounding air—and consequently ascends through the heavier air, which descends to supply its place; this, when heated, again ascends, other air descends, and so a constant series of currents is kept up, and purity of air ensured. As if this silent action were not sufficient, we have, as, in part, a consequence of the law, those powerful agents, the winds. Without periodical sea-breezes, many coasts and islands in the tropics would be quite uninhabitable. Their beneficial action is not confined to such regions. In all countries they are the great promoters of external ventilation; in proportion to their violence, sweeping before them the im-

purities with which the air may be charged, causing an effective change of it, and rendering especial service in maintaining its purity and healthfulness in crowded cities.

> Winds from all quarters agitate the air,
> And fit the limpid element for use,
> Else noxious: oceans, rivers, lakes and streams,
> All feel the freshening impulse, and are cleansed
> By restless undulation.

Carbonic acid, and other poisonous gases, with which the air becomes impregnated from various sources, are highly soluble in water; hence the important part which the rains, and the waters on the earth's surface, play in the great work of atmospheric purification. The rains, as they descend, absorb and carry down gases and foul emanations, and may literally be said to wash the air; while the countless miniature torrents, in passing from higher to lower ground, carry away offensive matters, and thus aid man's artificial efforts. When we consider the immense extent of ocean, that it covers nearly four-fifths of the surface of the globe, and when we think of the mighty mass acted upon by the hurricane, lashing winds and waves into conflict, we shall feel how important a part this agent must also take in the absorption of noxious gases and pestilential effluvia.

These various mighty agencies; the diffusion law; the law of expansion and diminished specific gravity of air under the action of heat, and the winds, which are in part the result of this; and, lastly, the absorption of noxious gases, and their removal by the rains, and by the waters of rivers, lakes, and ocean,—all tend to ensure the purification of the air we breathe. When we look, further, at the amazing bulk of the atmosphere itself,—that it extends out from the earth, and forms a layer round it forty-five miles in breadth—we shall see how long the removal of so much of its vital principle, the oxygen, and the diffusion of poisonous gases through its entire bulk, might go on, without its purity being materially impaired. The French chemist, Dumas, calculates that very many thousand years must elapse before the animals living upon the surface of the earth could seriously charge the atmosphere with carbonic acid, or absorb all its oxygen. But no possible, or remote contingencies even, are allowed in the schemes which result from the comprehensive forethought of Providence. To ensure, therefore, the impossibility of the atmosphere either sensibly losing its due proportion of oxygen, or sensibly acquiring an increase of carbonic acid, the latter, by an admirable provision, is made the food of plants,

and, through their agency, the lost oxygen is restored to the air.

I have already noticed the composition of common air, and the effects produced in it by the respiration of animals and man. I told you that air that had been breathed contained one-fourth or one-fifth less oxygen, and one hundred times more carbonic acid than it should do; and I also stated, that an adult man gives out twenty or more cubic feet of carbonic acid in twenty-four hours. When I tell you, further, that the human inhabitants of the earth amount, on the lowest calculation, to one thousand millions; and remind you, moreover, of the countless tribes of animals that inhabit the earth, air, and ocean, a number utterly beyond all calculation, you will conceive what a prolific source of carbonic acid animal life alone must be. The results of combustion going on in volcanoes, in our artificial lights and fires, our factories and furnaces, are, mainly, water and carbonic acid gas. A German naturalist, Schleiden, ingeniously calculates, from data founded on the produce of American and other tobacco-growing districts, that from tobacco-smoking alone we have a supply of carbonic acid in a year equal in weight to one thousand millions of pounds. In addition to these, there are numerous sources in nature, mineral springs and lakes

—to say nothing of the Grotto del' Cane, and the Poison Valley of Java,—from which prodigious quantities of carbonic acid gas are evolved. Now, while other gaseous impurities are removed by the action of laws which I have already noticed, as also is the carbonic acid, this latter gas is further summarily dealt with by the vegetable kingdom. This carbonic acid gas, on being taken into the system of plants, becomes resolved into its component elements, carbon and oxygen; the carbon is retained by plants as food, to build up their tissues, while the oxygen is again breathed out into the air for the purposes of animal life. Plants are provided with special organs, by which this process is effected. These organs consist of countless little pores or mouths, *stomata,* as botanists—preferring the Greek term to the unsophisticated English—call them. These stomata are sprinkled over the surfaces of the millions of leaves with which every tree is furnished, and are continually employed in separating carbonic acid gas from the atmosphere and inhaling it. It is calculated that a lilac-tree, with a million of leaves has about four hundred millions of these stomata at work. Many trees have at least ten millions of leaves engaged in the absorption of carbonic acid gas and the evolution of oxygen. When, therefore, we reflect on the immense extent of the

vegetable world, on the action of every blade of grass in incalculable acres of meadow and pasture land, of every leaf on every shrub or tree of garden, hedge-row, or forest,—remembering what Humboldt says of the forests in South America, that the trees are so thick and dense, and the forests so extensive, that monkeys may run for a hundred miles in a straight line on the tops of them,—we shall have the less difficulty in understanding the counterbalancing action of the vegetable world in maintaining the purity of the atmosphere. That plants do really perform this part in the economy of nature, has been directly proved by experiments; conducted on a small scale it is true, but perfectly conclusive. In the latter part of the last century, Lavoisier led the way in demonstrating what has been happily termed *nature's balance,* by showing the precise products of animal respiration. Senebier and De Saussure in France, and Dr. Priestley in England, followed in his steps, and demonstrated the results of the similar function in plants. Dr. Priestley was the first to believe, from certain experiments, that plants, instead of vitiating the air by their vegetation, reverse the effects produced in it by combustion and animal respiration, and thus maintain the purity of the atmosphere. By inserting plants in an air that had been pre-

viously vitiated by combustion and respiration, he found that the air was again restored to a condition capable of supporting those processes. One of his experiments was, to place a lighted candle in a closed bottle, and, when it had gone out from want of fresh air, to introduce therein a sprig of growing mint, which, after a time, was found to have restored the air to its original purity. On the occasion of presenting Dr. Priestley with the Copley Medal of the Royal Society in 1773, Sir John Pringle, the president, thus clearly expressed himself in reference to the balance of animal and vegetable respirations:—"From these discoveries we are assured that no vegetable grows in vain; but that, from the oak of the forest to the grass of the field, every individual plant is serviceable to mankind; if not always directly, by some private virtue, yet making a part of the whole, which purifies and cleanses our atmosphere. In this the friendly rose and deadly nightshade cooperate. Nor is the herbage nor the woods that flourish in the most remote and inaccessible regions unprofitable to us, nor we to them, considering how constantly the winds carry to them our vitiated air, for our relief and their nourishment." To Senebier, however, is due the credit of having shown the precise influence exerted by vegetables in decomposing the

carbonic acid given out in the processes of respiration and combustion; and in proving, further, that they exert this action under water as well as in air.

Dumas has, however, done more than any other chemical philosopher to prove the opposite parts played by animals and man in the scheme of nature; he has, in fact, shown, to use his own words, that "all that the atmosphere yields to plants, plants yield to animals, animals restore to the air. Eternal round, in which death is quickened and life appears, but in which matter merely changes its place and its form."

The vegetable kingdom, then, plays a very prominent part in counterbalancing the impurities resulting from animal life, and keeping the air in a fit state for the respiration of animals and man. In reference to man, it serves other purposes; furnishing him with food, either directly, or after it has become more highly elaborated in herbivorous animals; furnishing him, too, with exhaustless stores of fuel for industrial or domestic purposes, and playing a still higher part in ministering to his mind. But this is not all. Long before man appeared on the globe, in the earlier epochs of the earth's history, extensive tracts of giant vegetable life were engaged in separating from the atmosphere the carbonic acid gas, with

which it is supposed to have been far more highly charged than now; and, under the influence of a strong sunlight, decomposing this gas, fixing its carbon, and discharging the oxygen into the air. At an epoch succeeding to this, the air had become sufficiently purified for certain forms of animal life: huge reptiles, with sluggish habits and impure blood, capable of living on an air that would have been destructive to a higher order of life, appeared. At the same time, vast forests of pines, and ferns, and gigantic reeds, continued the work of purification, and stored up materials for those vast coal-fields, the long extinct vegetable life of which may be said now to be resuscitated in the steam-engine and its endless applications. At last, and as far as the earth's history goes, at a comparatively recent date, when the atmosphere had acquired its present constitution, there appeared upon the scene the higher animals and man.

THE END.

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